NASA Facts

National Aeronautics and
Space Administration

Marshall Space Flight Center
Huntsville, Alabama 35812

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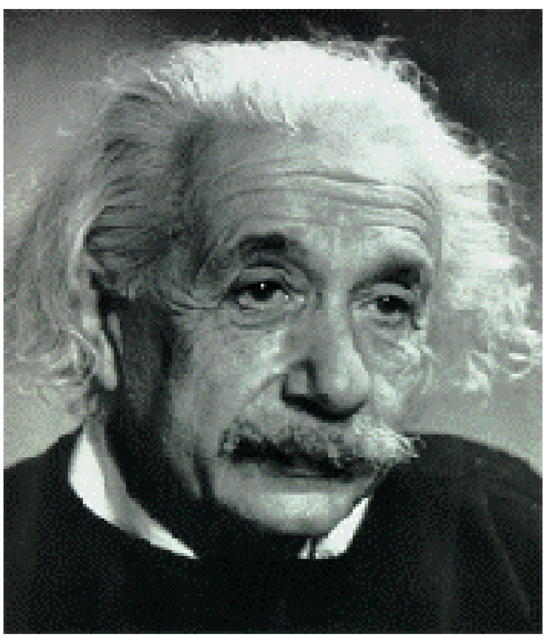
Gravity Probe B

Testing Einstein's Universe



NASA's Marshall Space Flight Center and Stanford University are developing a sophisticated experiment called Gravity Probe B (GP-B) to test Einstein's theory of General Relativity. Einstein's theory predicts that space and time are distorted by the presence of massive objects. Scheduled for launch in 2003, the GP-B mission will be among NASA's first to address a question of fundamental physics in the new millennium.

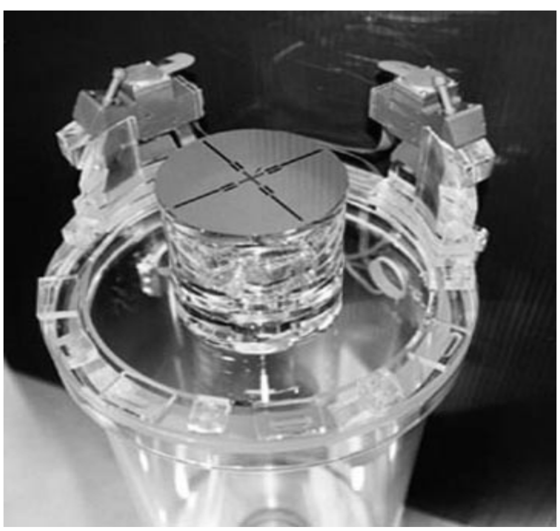
The Experiment

The GP-B experiment will contain the world's most precise gyroscopes. The gyroscopes have been specifically developed to measure two distinct effects of relativity. The first of these, the geodetic effect, is forecast to cause a change in the spin axis orientation of a gyroscope moving near any massive object. The second effect, known as frame-dragging, should result when a massive rotating body such as the Earth causes space-time to rotate around itself. The frame-dragging effect has never been directly measured.

Any geodetic and frame-dragging effects will be measured to exceptional precision by GP-B's gyroscopes. These measurements will help shape our understanding of Einstein's theory. If GP-B gives results consistent with General Relativity, it will help solidify our understanding of topics like black holes and the evolution of the universe. If, however, the results from GP-B are not consistent with Einstein's theory, it would significantly change the scientific perception of our universe.

NASA's Marshall Space Flight Center in Huntsville, AL, manages the Program. Stanford University in Stanford, CA conceived the experiment and is NASA's prime contractor for the Mission. Stanford is responsible for the design and integration of the science instrument, payload and spacecraft as well as conducting Mission Operations and Data Analysis. Lockheed Martin in Palo Alto, CA, is a major subcontractor on the project and is responsible for the design of the unique spacecraft and some of the major payload components.

Conceptually, the GP-B experiment is quite simple. A telescope is rigidly connected to the gyroscope housings. In flight the telescope always points to one guide star. The gyroscopes spin axes' are aligned through the bore sight of the telescope to the guide star. A superconducting readout system measures minute changes in each gyroscope's spin axis orientation. Changes in the spin alignment of the gyroscopes are a direct measurement of the geodetic and/or frame-dragging effects of General Relativity.



The GP-B Telescope

A GP-B Gyroscope

GP-B's gyroscopes are near perfect in that they limit any drift resulting from electrical and mechanical imperfections or forces acting on the gyroscopes. The GP-B instrument is designed to measure changes in gyroscope spin axis to better than 0.5 milliarcsecond — the width of a human hair seen from 15 kilometers (nine miles) away — over a one-year period.

According to the laws of Newtonian physics, a perfect gyroscope, which is experiencing no external forces, will not drift. In the GP-B experiment this would mean that once a gyroscope is spinning in alignment with the guide star, it would stay aligned with that star forever. In the early 1960's, using Einstein's theory of General Relativity, Dr. Leonard Schiff of Stanford predicted that the geodetic and frame-dragging effects would slightly change an orbiting gyroscope's alignment in relation to the star.

GP-B's Technology

All the major components of the science instrument (four gyroscopes, the optical telescope, the mounting block) are made of fused quartz. Quartz is virtually unaffected by temperature changes, neither expanding nor contracting. Speedring, Inc., in Cullman, AL, machined many of the precision parts of the instrument, including the gyroscope housings.

The science instrument's optical telescope has an aperture of 14 centimeters (5.5 inches). It will point toward GP-B's guide star IM Pegasus (HR 8703), which will become the experiment's frame-of-reference in space.

Technicians at the Marshall Center originally built the highly advanced polishing equipment needed to manufacture the gyroscope rotors. Engineers at Stanford developed the thin-film technology for placing a superconductive metal coating of Niobium on the gyroscope rotors.

The gyroscope rotors are considered the most spherical objects ever made. If the gyroscope rotor were the size of the Earth, the tallest mountain and the deepest ocean ravine would differ by only 4.88 meters (+/- 8 feet) in height. These gyroscopes are sufficient to achieve the specified 0.5 milliarcsecond per year drift rate measurement.

The Cryogenic Probe

The GP-B instrument assembly is contained within the 2.74-meter (9 foot) long, cigar-shaped "Cryogenic Probe". This, in turn, is contained within a large thermos-like "Dewar", containing 2,441 liters (645 gallons) of supercooled helium. The extremely low temperature of 1.8 Kelvin is necessary to cause the Niobium metal coating on the gyroscope rotors to become super-conducting. The direction of the rotor spin axis is determined magnetically through the magnetic moment ("London moment") generated by a spinning super conductor.

The Dewar

Supercooled, or superfluid helium, is so cold that almost all molecular motion has stopped. As the helium gradually boils off into space, some of the gas will be vented through special valves or "thrusters" to keep the spacecraft in the proper orientation and "drag free".

To prevent the liquid helium from flowing out in the micro-gravity of space, a porous plug was created. Some of the evaporating gaseous helium will flow out through this plug and provide additional cooling for the instrument and provide the propulsive gas for the thrusters.

Inside the Dewar surrounding the Probe is a shield of superconducting lead foil. This "lead bag" shields the instrument from interference from the Earth's magnetic field.

The Spacecraft ready for testing

The Mission

The GP-B Spacecraft is scheduled to launch from Vandenberg Air Force Base, CA, aboard a Boeing Delta II rocket in late Fall, 2003. The Spacecraft (or Space Vehicle once in space) will be inserted into an almost perfect circular polar orbit around the Earth at an altitude of 640 kilometers (400 miles).

As the Space Vehicle orbits, it will slowly rotate around its own axis thereby virtually eliminating thermal effects and other tiny forces acting on the gyroscopes that are unrelated to the effects of General Relativity.

Data from GP-B will be received a minimum of two times each day. Either Earth-based ground stations or NASA's data relay satellites can receive the information. Controllers will be able to communicate with the orbiting Space Vehicle from the Mission Operations Center at Stanford.

Data will include Space Vehicle and instrument performance, as well as the gyroscopes' measurements of relativity. By 2005 the GP-B mission will be complete, and the data will have been analyzed.

Einstein's Legacy

We will be in a position to compare measured values of any geodetic and frame-dragging effects with the theoretical values resulting from Einstein's 1916 theory of General Relativity. Will the Time magazine "Man of the (20^{th}) Century" be right? Tune in to find out.

Technical Details

Space Vehicle	
Length	6.43meters (21 feet)
Diameter	2.64 meters (8.65 feet)
Mass	3,100 kilograms (6,820 pounds)
Optical Telescope	
Aperture	14 centimeters (5.5 inches)
Focal Length	3.81 meters (150 inches
Mirror Diameter	14.2 centimeters (5.6 inches)
Helium Dewar	
	2,441 liters (645 gallons)
Launch Vehicle	
	Boeing Delta II rocket
Orbit altitude	
	640 kilometers (400 miles)
Guide star	
	HR 8703 (IM Pegasus)

For more information, see:
http://einstein.stanford.edu and
http://www.gravityprobeb.com